Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.1 Distinguish chemical properties of matter (including reactivity) from physical properties of matter (including boiling point, freezing/melting point, density [with density calculations], solubility, viscosity, and conductivity).
Taxonomy Level: 4.1-B Analyze Conceptual Knowledge

Key Concepts:
Physical property: boiling point, freezing/melting point, density, solubility, viscosity, conductivity
Chemical property: combustibility, flammability; ability to oxidize, corrode, decompose, react with acids; not react

Previous/Future knowledge: Students were introduced to this topic in 7th grade (7-5.9). A more in-depth understanding of the actual processes is expected for Physical Science. Distinguishing between physical and chemical properties is the foundation for an understanding of the distinction between chemical reactions and physical change (PS-4.6) and, therefore, vital to an understanding of chemical reactions in (PS-4.7) through (PS-4.11) and all future chemistry courses.

It is essential for students to know the criteria for distinguishing chemical from physical properties:
- A physical property of a substance is a characteristic of the substance that can be observed directly or measured with a tool without changing the composition of the substance.
- A chemical property is a description of the ability of a substance to undergo, or not undergo, a change that will alter the composition of the original substance.

Physical Properties
It is essential for students to understand the following physical properties:

Boiling point, freezing/melting point – students should
- Know that the terms boiling point and melting/freezing point do not refer to the phase change itself, but to a measurement: the temperature at which these changes occur.
- Understand that the composition of a substance does not change during phase change nor does it change when one measures temperature in order to determine the boiling point, and freezing point/ melting point, therefore, boiling point and melting/freezing point are physical properties.

Misconception:
As the physical appearance of a substance changes during a phase change, students often mistakenly assume that evaporation and freezing/melting are chemical changes (see PS-4.6). This misconception is often encountered with evaporation where students confuse vaporization of material A from liquid (A) to gas (A) with the formation of a new gas (B) by a chemical reaction.

It is not essential for students to
Understand the effect of pressure on the boiling point or the freezing/melting point of a substance.

Properties and Classifications of Matter

PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

***Density* –** students should

- Understand the concept of density as the mass of a substance per unit volume. A conceptual understanding of density ensures that students understand why the density of a particular substance (under constant conditions) is always the same, regardless of the sample size.
- Understand why the density of a substance changes with phase change. PS-3.7 addresses the difference in the particle arrangement in solids, liquids and gases. Students should understand that because the volume of a particular substance is dependent upon phase, the density of a particular substance is as well.
- Understand that density can not be measured directly, but is the ratio of two measurements: mass and volume.
    - Students must have a strong conceptual understanding of mass and volume.
    - In addition, it is essential that students understand and are proficient at carrying out the procedures for accurately measuring the mass and volume of solids (regularly and irregularly shaped) and liquids (PS-1.3).
- Understand and calculate density using the formula: density = mass/volume.
- Understand that the composition of a substance does not change when one measures mass and volume in order to calculate density; therefore, density is a physical property.

Misconception:

Students can often manipulate and solve the density equation without a grasp of the proportional thinking required to truly understand the concept. Understanding a ratio requires that students think abstractly, a cognitive skill that many physical science students have not yet acquired. Therefore, it is essential that this concept be introduced in a concrete manner.

It is not essential for students to

Understand the effect that temperature change (apart from phase change) has on volume (therefore, the density) of solids, liquids, or gases.

***Solubility* –** students should

- Understand that a substance is soluble in a solvent if it will dissolve in that solvent. The term solubility is defined as the maximum amount of a solute (substance being dissolved) that can dissolve in a given volume of solvent (the dissolving medium) at a particular temperature and pressure.
- Understand that a *saturated* solution is one in which the maximum mass of the solute is dissolved in the solvent at a particular temperature.
- Be able to give examples of solids, liquids, and gases that readily dissolve in water and to realize that some materials are not soluble in water.
- Understand that the components of solutions and other mixtures do not chemically combine to form a new substance. Solutions are composed of two substances which each retain their own properties. Therefore, solubility is a physical property.

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

Note to teachers:

In Physical Science, solubility is defined as a physical property because solutions are defined as homogeneous mixtures. As students study chemistry they will find that the dissolving process varies with the characteristics of the solute and the solvent respectively. The attraction of various solute particles to water molecules varies and if this force is strong, the dissolving process is followed by reactions that are chemical in nature as the solute particles interact with the solvent particles. It is not essential for Physical Science students to be aware of this, but if they find conflicting information in texts, an explanation should follow.

Misconceptions:

- Students often confuse solubility with the rate of dissolving (see PS-3.5).
- As the physical appearance of a substance changes when it dissolves (the solute often disappears) students often mistakenly assume that dissolving is a chemical change (PS-3.6). In a solution, the solute and solvent do not chemically combine, they form a homogenous mixture. (PS-3.4)

It is not essential for students to

- Consider solubility of substances in solvents other than water.
- Consider the effect of pressure on solubility.
- Predict the effect that temperature has on the solubility of a given substance. (It is interesting, but not essential, to contrast the effect that temperature has on the solubility of gases versus most solids and to consider the many results and applications of temperature-dependent solubility in our world.)
- Understand how to read temperature vs. solubility graphs.

Viscosity **–** students should

- Understand that viscosity is a property of fluids (focus on liquids, not gases).
- Understand that viscosity is a measure of the material's resistance to flow. High-viscosity fluids take longer to pour than low-viscosity fluids.
- Understand that viscosity may change with temperature.
- Understand that the composition of a fluid does not change when it is poured and, therefore, viscosity is a physical property.

It is not essential for students to

Use specialized apparatus to test and measure viscosity.

Electrical Conductivity **–** students should

- Understand that the ability of a solid to act as an electrical conductor or an electrical insulator is based on the solid's ability to complete an electric circuit, i.e., conduct electricity. (see indicator PS-6.9 for electric circuits)
- Understand that materials (such as metals) with high conductivity are called electrical conductors because they allow current to flow easily.
- Understand that materials with low conductivity are called electrical insulators because they do not allow current to flow. Most non-metals are insulators.

- Understand that some solutions can conduct electric current, depending on the nature of the solute. Solutes that dissolve in water that result in solutions that allow electric current to flow are called *electrolytes*. Electrolyte solutions contain *ions*.

It is not essential for students to

Know the relationship among the terms electrical conductor, electrical resistivity, and electrical resistance.

Chemical Properties

It is essential for students to

- Understand that a *chemical property* is a characteristic of a substance that indicates whether it can or cannot undergo a certain chemical change.
- Understand that the process of chemical change produces new substances with new identifying properties.

Chemical properties include but are not limited to:

- *Combustibility or flammability*, such as carbon reacting with oxygen to form carbon dioxide. (example, burning charcoal), or hydrocarbons reacting with oxygen to form carbon dioxide and water vapor (example, burning of fossil fuels)
- *Ability to oxidize*, such as iron reacting with oxygen to form iron(III) oxide. (iron rusting)
- *Ability to corrode*, such as silver reacting with sulfur to form silver sulfide. (silver tarnishing)
- *Ability to decompose*, such as hydrogen peroxide decomposing into water and hydrogen gas when exposed to light.
- *Ability to react with acids*, such as zinc reacting with hydrochloric acid to form zinc chloride and hydrogen gas.
- *Ability to not react*, such as gold being used in jewelry because it does not readily react.

Assessment Guidelines:

The objective of this indicator is to *distinguish* chemical properties of substances from physical properties (solubility, viscosity, conductivity, density, boiling and freezing point), therefore, the primary focus of assessment should be to identify the relevant or important aspects of each property necessary for classification. In this case, the composition of the substance does or does not change when the property is measured, as well as an understanding of the distinction between chemical and physical properties.

In addition to distinguishing chemical and physical properties, assessments may require that students:

- *Classify* properties as physical or chemical.
- *Identify* physical and/or chemical properties of a substance.
- *Exemplify* (give examples) chemical and physical properties.
- *Use* the mathematical formula for density to solve for one of the variables when given the other two.

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.2 Infer the practical applications of organic and inorganic substances on the basis of their chemical and physical properties.
Taxonomy Level: 2.5-B Understand Conceptual Knowledge

Key Concepts:
Organic substances: biological molecules - protein, carbohydrate, lipid; hydrocarbons - polymers
Inorganic substances

Previous/Future knowledge: Students have not been introduced to this topic in any previous grade. Distinguishing between organic and inorganic substances is a foundation for an understanding of two major areas of chemistry.

It is essential for students to
- Select the best substance for a particular function when given a list of the substance's chemical and physical properties.
- Understand that all organic substances are compounds that contain carbon, and that inorganic substances are elements or compounds (that do not necessarily contain carbon).

Organic Substances
- Understand that the functions of substances are dictated by their properties. Recall the names of selected types of organic *biological molecules* and summarize how their functions in organisms are dictated by their chemical properties. Examples include:
  - *Protein* molecules are long chains of small units (amino acid monomers) that are arranged in various configurations so they can form a wide variety of molecules. Proteins serve many varied functions in living organisms such as catalysts (enzymes) and tissue building.
  - *Carbohydrate* molecules (sugars and starches) provide organisms with energy when they break down into smaller molecules.
  - *Lipid* molecules (fats and oils) are good sources of stored energy because lipids produce more energy per gram than carbohydrates.-
- Recall that *hydrocarbons* are a class of organic molecules composed of the elements carbon and hydrogen. Carbon and hydrogen can combine to make thousands of different hydrocarbon compounds.
  - Recognize that many hydrocarbons are combustible so they are used for fuel, including gasoline, kerosene, jet fuel, and diesel oil.
  - Recognize that many hydrocarbons form long chain molecules called *polymers* so they are used to make plastics and synthetic fibers.

Inorganic Substances
- Recognize potential uses of inorganic substances when given the properties of the substance. Examples include:
  - Copper is ductile and conducts electricity, so it is used in wiring.
  - Aluminum has a low density compared to substances with similar strength, so it is used in making airplanes.
  - Water is a good solvent for many compounds, so it is used to wash clothes.
  - Argon is an inert/stable gas that will not react with the filament, so it is used in light bulbs.

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

It is not essential for students to
- Recall the structural formulas of organic compounds.
- Recall organic nomenclature.

Assessment Guidelines:
The objective of this indicator is to *infer* applications of organic and inorganic substances based on physical and chemical properties, therefore, the primary focus of assessment should be to choose an appropriate substance for a particular practical application when presented with the chemical and physical characteristics of several substances or to determine the chemical and physical properties that a substance would need to have in order to be useful for a particular practical application.

In addition to *infer*, assessments may require students to
- *Classify* substances as organic or inorganic when given a description of the components of the compound (based on the presence or absence of carbon);
- *Exemplify* the use of organic and inorganic substances based on their properties;
- *Summarize* how the practical applications of organic and inorganic substances.

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.3 Illustrate the difference between a molecule and an atom.
Taxonomy Level: 2.2-B Understand Conceptual Knowledge

Key Concepts:
Molecule
Atom
Atoms can combine to form molecules

Previous/Future knowledge: In 7th grade, students recognize the atom as the basic building block of matter (7-5.1).
In Physical Science indicators PS-2.1 through 2.4 addressed the parts and properties of atoms. This indicator is meant to introduce students to the concept of chemical bonding. PS-3.4 will require that students classify matter as pure substance or mixture. In preparation for this skill, students must understand the implications of atoms bonding to form molecules. This standard lays the foundation for one of the major types of chemical bonding (PS-4.1 through PS-4.5).

It is essential for students to
- Understand that elemental substances (elements) are composed of only one type of atom.
- Understand that an atom is the smallest unit of an element that can be involved in a chemical reaction.
- Understand that all of the elements are listed on the periodic table.
- Understand that molecular substances are composed of two or more atoms covalently bonded together to make units called *molecules*.
- Understand that a molecule is the smallest particle of a molecular substance that can exist and still have the composition and chemical properties of the substance.

Teacher note: This indicator is an introduction to bonding; illustrating shared electrons and bonding will be addressed in PS-4.1 through PS-4.5.
- Understand the chemical and physical properties of a molecular substance are different from the chemical and physical properties of the component elements.
- Give examples (illustrations) of substances composed of molecules and examples of substances composed of individual atoms (as indicated by the verb illustrate).
  - Examples of molecules may include: CO_2 , SO_2 , H_2O , H_2
  - Examples of individual atoms may include: Na, Ar, He, Cu,
  - Illustrations may be in the form of chemical names, chemical symbols/formulas, verbal descriptions, or pictorial diagram

It is not essential for students to
- Remember all of the chemical formulas for substances;
- Be familiar with chemical nomenclature – writing chemical names;
- Understand that the atoms in metallic substances such as copper are held together by metallic bonds.

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

Assessment Guidelines:
The objective of this indicator is to *illustrate* the difference between a molecule and an atom, therefore, the primary focus of assessment should be to give or use illustrations that show the differences in words, pictures, or diagrams between atoms and molecules.

In addition to *illustrate*, assessments may require students to

- *Classify* substances as atoms or molecules when given the chemical names, chemical formula/symbols, verbal descriptions, or pictorial diagrams of substances, and give the reason the category chosen;
- *Summarize* the differences between atoms and molecules in terms of structure;-
- *Compare* atoms to molecules, in terms of structure.

PS-3.4 Classify matter as a pure substance (either an element or a compound) or as a mixture (either homogeneous or heterogeneous) on the basis of its structure and/or composition.
Taxonomy Level: 2.3-B Understand Conceptual Knowledge

Key Concepts:
Pure substance: Element, Compound
Mixture: Homogenous mixture, Heterogeneous mixture

Previous/Future knowledge: In 7th grade (7-5.2), students classify matter as element, compound, or mixture on the basis of composition.
In Physical Science (PS-2.1), students developed and understanding of elements as composed of only one type of atom. (PS-3.3) added that molecular substances are composed of two or more types of atoms that are bonded together as molecules and that molecular substances do not retain the properties of their components but have their own identifying properties (PS-3.3).
This indicator lays the foundation for an understanding of chemical reactions (PS-4.8).

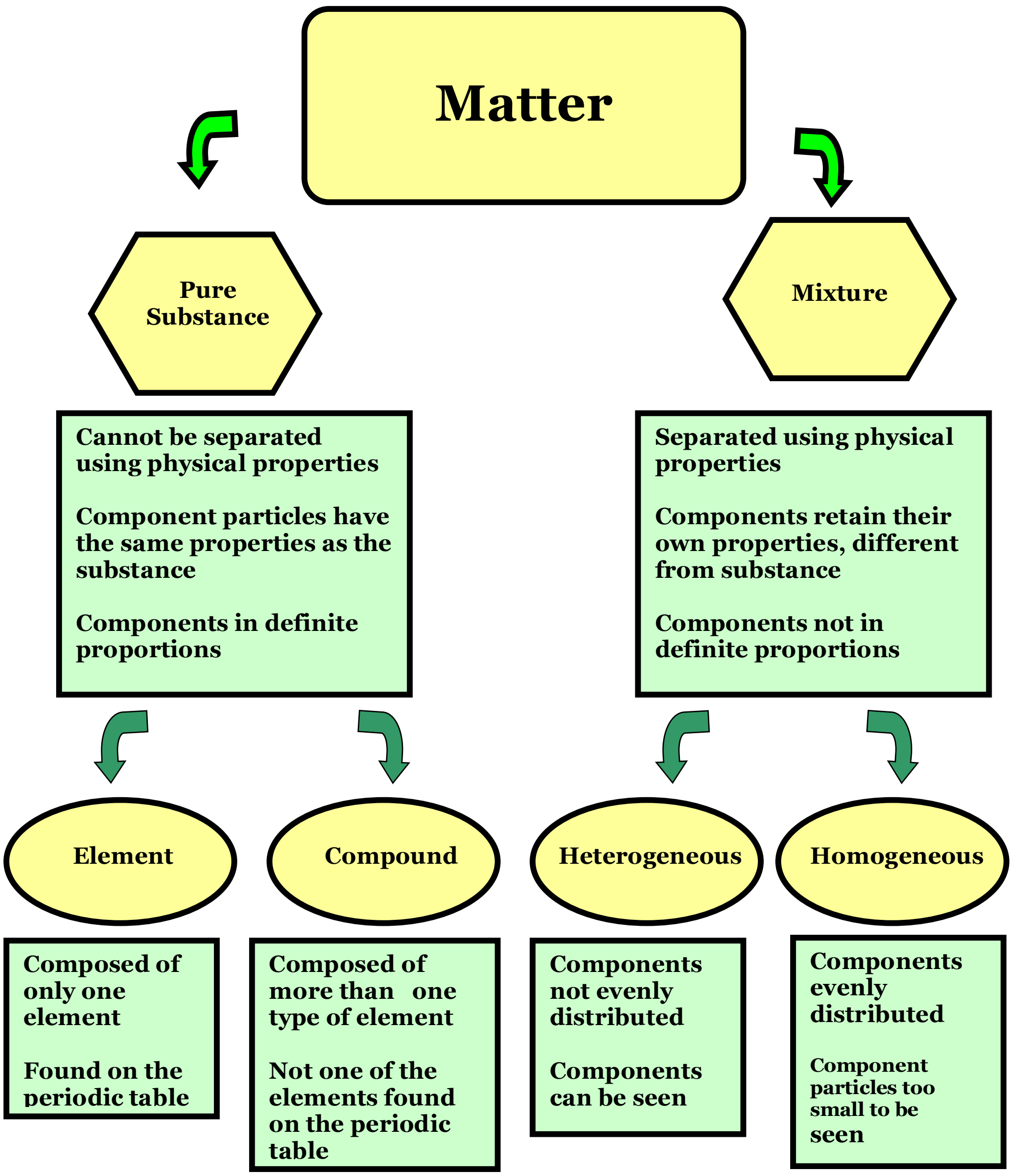
It is essential for students to
- Understand that substances that have unique, identifying properties are called *pure substances*. There are two types of pure substances, elements and compounds.
    - An *element* is a pure substance which is composed of only one type of atom. All of the elements are listed on the periodic table
    - A *compound* is a pure substance which is composed of more than one type of element.
        - Compounds all have identifying properties which are different from the properties of the elements which compose them.
        - Compounds can be decomposed into elements only by chemical reactions; they can not be separated into elements by physical means.
        - Compounds have a definite chemical composition identified by a chemical formula. For example, the ratio of the number of oxygen atoms to hydrogen atoms in any sample of water is always 1 to 2.
        - Molecular substances are one type of compound, and ionic substances are another type of compound (this is addressed further in PS-4.1 through PS-4.5).
- Understand that when matter is composed of two or more component substances which retain their own identifying properties, the matter is classified as a *mixture.*
    - A mixture can be separated physically because the components of the mixture have different physical properties. (PS-3.1) Examples of procedures for separating mixtures based on differing properties include but are not limited to:

• Dissolving	• Filtering	• Evaporating
• Decanting	• Magnetic separation	• Chromatography
• Separating by particle size (screening)		

- Mixtures do not have definite composition; the components of a mixture may be in any ratio.
- Mixtures can be classified into two groups, heterogeneous and homogeneous.
    - *Heterogeneous mixtures* do not have the components distributed evenly throughout. The different components are often easy to see in a heterogeneous mixture.

  - *Homogeneous mixtures* have components evenly distributed all the way down to the particles, whether atoms, molecules, or ions. The components are so small that they can not be seen with the naked eye. A *solution* is a homogeneous mixture. (Ions will be addressed in PS-4.2.)
- Understand that mixtures can occur between and among all phases of matter:
  - Gas/gas (air)
  - Gas/liquid (oxygen in water)
  - Liquid/liquid (alcohol in water)
  - Solid/liquid (sugar in water)
  - Solid/solid (alloy such as steel)

The following graphic organizer is a way for students to organize their thinking.



Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

It is not essential for students to
- Understand colloids or suspensions;
- Understand colligative properties.

Assessment Guidelines:
The objective of this indicator is to *classify* matter as a pure substance or a mixture, therefore, the primary focus of assessment is to group pure substances or mixtures on the basis of the criteria for each category, and to further group pure substances as an element or a compound, and mixtures as a homogeneous or a heterogeneous mixture.

In addition to *classify*, assessments may require that students
- *Exemplify* a pure substance, mixture, element, compound, heterogeneous mixture, homogeneous mixture/solution, and justify the example;
- *Compare* one of the given categories to another as to relevant characteristics which define each category;
- *Summarize* the major points which define each category.

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.5 Explain the effects of temperature, particle size, and agitation on the rate at which a solid dissolves in a liquid.
Taxonomy Level: 2.7-B Understand Conceptual Knowledge

Key Concepts:
Kinetic Theory
Temperature (effect on particle motion)
Particle size (effect on surface area)
Agitation (effect on solute/solvent collisions)

Previous/Future knowledge: In 5th grade (5-4.6) students explained how temperature change and stirring affect the rate of dissolving, but at this point students are only required to understand that these factors do have an affect on the rate of dissolving, not why. 5th grade students were introduced to the particulate nature of matter (5-4.1). In 7th grade students recognized that matter is composed of extremely small particles called atoms (7-5.1).
Indicator PS-3.4 introduced Physical Science students to a solution as a homogeneous mixture in which the components are close to the size of individual particles of the substance (atoms, molecules, or ions) and, therefore, too tiny to be seen with a microscope.

It is essential for students to
- Understand the three basic assumptions of kinetic theory.
  - All matter is composed of small particles (molecules, atoms, and ions).
  - The particles are in constant, random motion.
  - The particles are colliding with each other and the wall of their container.
- Understand the process of dissolving in terms of the kinetic theory.
  - The solvent (in this case water) is composed of individual water molecules (H_2O), all close enough to touch, but in constant motion, moving over, under, and past one another. (see liquids PS-3.6)
  - The solute (such as table sugar) is composed of crystals.
    - Each crystal is composed of billions of individual sugar molecules. The individual molecules are attracted to each other (not chemically bonded) together. The sugar molecules in the crystal are also moving but because sugar is a solid (See PS-3.6) the molecules do not move past each other, they vibrate in place.
    - Because sugar is a molecular compound, the individual sugar molecules can not be decomposed by a physical process such as dissolving, so the dissolved sugar remains as sugar molecules and not separated carbon, hydrogen and oxygen atoms.
    - The dissolving process involves the sugar molecules being pulled <u>away from each other</u> by the water molecules but each molecule of sugar remains intact.
    - The sugar molecules on the surface of the crystal are the only ones to dissolve because they are the ones in contact with the water molecules. As surface sugar molecules dissolve, they expose the ones beneath to the water.
    - Because the dissolved sugar molecules are surrounded by water molecules, they are not attracted to each other (the water molecules block the attractive force).
    - In the resulting solution, the sugar molecules are distributed throughout the water.

        - The water can be removed by boiling the water or allowing it to evaporate. When the water boils or evaporates away, the sugar molecules will once again be attracted to each other and sugar crystals will reform.
- Understand how temperature affects the rate at which substances dissolve.
    - The higher the temperature, the faster the rate of dissolving for a solid in a liquid.
    - At higher temperatures more of the solvent molecules are moving faster and collisions with the surface of the solute occur more often carrying off particles of the solute so dissolving occurs more rapidly.
- Understand how particle size affects the rate at which substances dissolve. (Are they large chunks of material or ground into many small pieces as in a powder?)
    - The smaller the size of the pieces of solute, the faster they dissolve.
    - The smaller the size of the individual pieces, the more surface area the sample will have to be in contact with the water molecules. With more surface area in contact the water molecules, the water will have more opportunities to pull the solute molecules away from the solute's surface, thereby, dissolving it faster.
- Understand how agitation affects the rate at which substances dissolve.
    - The more the solution is agitated, the faster the rate of dissolving for a solid in a liquid.
    - When a solution is agitated, the water particles collide with the surface of the solute more frequently and the dissolving process occurs faster.
- Understand that if a substance is soluble in water, it will eventually dissolve even if the size of the sample pieces of solute are large, the temperature is low and there is no agitation.

Misconception: Students often confuse rate of dissolving (how fast a substance dissolves) with solubility (what quantity of a substance can dissolve) (see PS-3.1).

It is not essential for students to
- Understand the intermolecular forces within a molecular crystal;
- Understand the energy of solution;
- Understand the polar nature of the water molecule;
- Differentiate polar and non-polar solvents.

Assessment Guidelines:
The objective of this indicator is to <u>*explain*</u> the effects of temperature, particle size, and agitation on rate of dissolving, therefore, the primary focus of assessment should be to construct cause and effect models based on kinetic theory that show the effect each variable has on the rate of dissolving. The cause and effect here is not "the solute dissolves faster because the particle size is smaller" but rather "smaller particle size increases the rate of dissolving because when a substance is in smaller pieces, there is more surface area exposed to collide with the solute molecules."

In addition to *explain*, assessments may require that students
- <u>*Compare*</u> the dissolving rate of solutions that differ according to one of the indicator variables;
- <u>*Summarize*</u> the effect of the factors influencing the rate of dissolving; or
- <u>*Recall*</u> the effect of the indicator variables on the dissolving process.

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.6 Compare the properties of the four states of matter—solid, liquid, gas, and plasma—in terms of the arrangement and movement of particles.
Taxonomy Level: 2.6-B Understand Conceptual Knowledge

Key Concepts:
Kinetic theory
States of Matter: solid, liquid, gas, plasma

Previous/Future knowledge: In 5th grade (5-4.2) students compared the physical properties of the states of matter (including volume, shape, and the movement and spacing of particles). This concept has not been revisited since that time.
Although the 5th grade and Physical Science indicators appear to be similar, Physical Science students develop a mental image of atoms and molecules and are conceptually prepared for a deeper understanding of the phases of matter in terms of the kinetic theory.

It is essential for students to
- Understand the kinetic theory; (see PS-3.5)
- Understand the characteristics of solids, liquids, gases, and plasma in terms of the kinetic theory.

Solids	• The particles of solids are closely packed together because there is an attractive force holding them together • The particles of solids are constantly vibrating, but they do not readily slip past one another. • Because the particles vibrate in place and do not readily slip past one another, a solid has a definite shape.
Liquids	• The particles of liquids are in contact with each other because there is an attractive force holding them together. • The particles of liquids have enough energy to partially overcome the attractive force of the surrounding particles. Liquid particles can slip past surrounding particles and slide over one another. Because the particles slip past one another, a liquid does not have a definite shape and so takes the shape of the container. A sample of a liquid can be poured.
Gases	• The particles of gases are not in contact with each other because they have enough energy to completely overcome the attractive force between or among the particles. • The particles of gases are moving randomly, in straight lines until they bump into other particles or into the wall of the container. When a particle hits another particle or the container, it bounces off and continues to move. • Because gas particles move independently, the particles move throughout the entire container. The forces between the particles are not strong enough to prevent the particles from spreading to fill the container in which the gas is located.

Plasma	• Plasma is matter consisting of positively and negatively charged particles. • A substance is converted to the plasma phase at very high temperatures, such as those in stars (such as the sun). High temperature means that the particles of a substance are moving at high speeds. At these speeds, collisions between particles result in electrons being stripped from atoms. • Plasma is the most common state of matter in the universe, found not only in stars, but also in lightning bolts, neon and fluorescent light tubes and auroras.

It is not essential for students to

- Differentiate crystalline from amorphous solids (Addressed in subsequent chemistry classes);
- Understand various crystalline structures or types of packing (Addressed in subsequent chemistry classes);
- Understand various intermolecular forces (Addressed in subsequent chemistry classes);
- Convert Celsius temperature to Fahrenheit.

Misconceptions: Students often believe that at a given temperature the particles of all liquid substances are moving faster than the particles of all solid substances, and that the particles of gaseous particles are moving fastest of all. It is important that students understand that at a given temperature, all matter has the same average kinetic energy and that in each sample there are particles moving at all different rates of speed. As temperature increases, more particles move fast, fewer particles move slowly. The reason that various types of matter are in various phases at a given temperature is primarily due to the variation in the strength of the forces between the particles of various substances. Materials change phase when they absorb enough energy to break/overcome the attractions between the particles of which they are composed.

Assessment Guidelines:
The objective of this indicator is to *compare* the properties of the phases of matter with regard to the arrangement and motion of particles, therefore, the primary focus of assessment should be to detect similarities and differences between the phases of matter showing understanding of the reasons for particle arrangement and movement in terms of the kinetic theory.

In addition to *compare*, assessments may require that students

- *Illustrate* with words, pictures, or diagrams particle motion and arrangement in a solid, liquid, gas, or plasma;
- *Classify* a substance as a solid, liquid, gas, or plasma based on a description of the particle arrangement and motion;
- *Summarize* the characteristics of the particle motion in solids, liquids, gas, and plasma;
- *Recognize* the four states of matter by their characteristics.

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.7 Explain the processes of phase change in terms of temperature, heat transfer, and particle arrangement.
Taxonomy Level: 2.7-B Understand Conceptual Knowledge

Key Concepts:
Temperature
Phase change (in terms of energy): freezing/melting point, boiling point, sublimation
Temperature change (in terms of energy)
Heat Energy

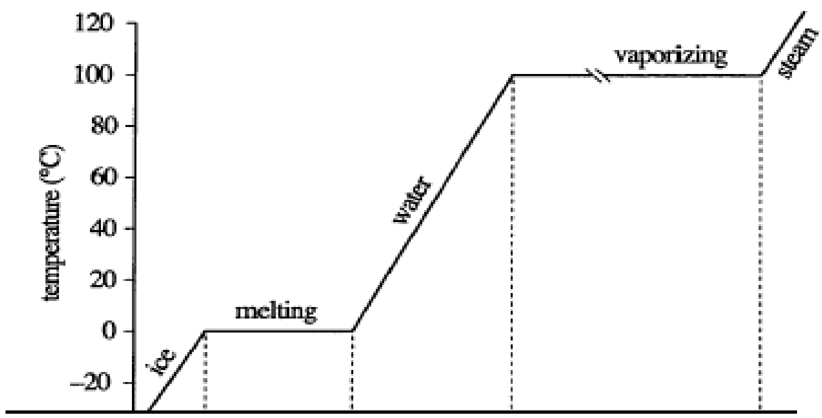
Previous/Future knowledge: Students in 3rd grade explained how water and other substances change from one state to another (including melting, freezing, condensing, boiling, and evaporation (3-4.2). In 7th grade students revisited changing states of matter as a physical change along with melting and boiling points as properties.
The Physical Science indicators appear to be very similar to 3rd grade, but Physical Science students have developed a conceptual image of atoms and molecules and are more cognitively prepared for a deeper understanding of phase change in terms of the kinetic theory and energy changes.

It is essential for students to
- Understand that *temperature* is a term used to describe the average kinetic energy of the particles in a substance. In a sample of material at any temperature there are particles moving at all speeds. Temperature is a measure of the average motion of the particles. At higher temperatures, more of the particles are moving fast and at lower temperatures, more of the particles are moving slowly.
- Explain *phase change* in terms of the kinetic theory.
  - Phase change is due to *changing* the freedom of movement of the particles by the addition of energy.
  - The freezing/melting point is the temperature where a phase change occurs as both the liquid and solid phases exist in equilibrium with each other. If heat energy is being <u>added</u> at this temperature, bonds between particles will break and a solid will melt. If heat energy is being <u>taken away</u>, bonds will form between particles and a liquid will freeze at this temperature.
  - The boiling point is the temperature where a liquid is changing to a gas throughout the liquid. Evaporation at the surface of a liquid can occur at any temperature. However, at the boiling point bubbles of the vapor are formed throughout the sample and rise to the top and escapes at which point the sample is said to be boiling.
- Understand that when energy (such as heat) is added to a substance, the energy of the particles of the substance increases. Evidence of this would be that: (1) the temperature of the substance increases, or (2) a phase change occurs.
- Understand that when heat is added to a solid the particles will move faster and the temperature will increase until the temperature of the solid reaches its melting point.
  - When the temperature of a solid is equal to the *melting point* and more heat is added to the substance, the temperature will not change. The extra heat will be used to break some of the bonds between the molecules of the solid and change the phase to a liquid.
- Understand that when heat is added to a liquid the particles will move faster and the temperature will increase until the temperature of the liquid reaches its boiling point.

- When the temperature of a liquid is equal to the *boiling point* and more heat is added to the substance, the temperature will not change. The extra heat will be used to break the bonds between the molecules of the liquid and change the phase to a gas. When a substance boils, it forms bubbles of the gas. (For example when water boils, the bubbles are filled with water vapor.)

- Understand the changes shown on a temperature versus time graph that shows boiling point and melting/freezing point.
  - The line of the graph has a positive slope until a phase change occurs.
  - At the melting point or boiling point the temperature does not change as more heat is added over time. The slope of the line will be flat during the time that the phase is changing.
  - After the phase change the slope of the line becomes positive again.

Heat Added Over Time



time (s)

- Understand that liquids may evaporate at any temperature. This is because some of the molecules at the surface are moving fast enough to escape the attraction of the other molecules.
- Understand that solids may undergo the process of *sublimation*, a process that involves particles changing directly from the solid phase to the gaseous phase. This is a process similar to evaporation that takes place at the surface of the solid.
  - An example of sublimation is seen when dry ice (solid carbon dioxide) disappears as it changes directly to gaseous carbon dioxide without melting first.

Misconceptions:

- Students often confuse heat with temperature.
  - Sometimes it is helpful to point out that a huge pot of very hot water and a coffee cup of very hot water can both have the same temperature, but the pot of water contains much more heat energy than the water in the cup because the mass of the water in the pot is so much greater.
  - This concrete example helps students to understand that there is a distinction in the two concepts, even though it is beyond the scope of this course for students to fully explore the distinction in the two.
- The only distinction that is essential for Physical Science students to make is that heat is a form of energy and temperature is an indication of the average kinetic energy (and therefore the speed) of the particles.

It is not essential for students to

- Understand the effect that pressure has on phase change;
- Differentiate heat and temperature in quantitative terms (Addressed in subsequent chemistry/physics classes);
- Understand how the mass of the particles of a substance affect the energy of the particles.

Assessment Guidelines:
The objective of this indicator is to *explain* the processes of phase change in terms of temperature, heat transfer, and particle arrangement, therefore, the primary focus of assessment should be to construct cause and effect models of phase change based on the kinetic theory of matter. The cause and effect required by assessment is not a statement such as "the solid melts because heat is added when it is at a temperature equal to its melting point"; the cause and effect required by assessment is a model of the system such as "a solid will melt when the solid absorbs enough energy at its melting point to overcome/break the attractive forces between the particles."

In addition to *explain*, assessments may require that students

- *Illustrate* with words, pictures, or diagrams phase change processes related to energy change;
- *Recognize* what happens to temperature between phase changes and during phase change;
- *Summarize* major points about what happens to particles and particle arrangement during phase change in terms of kinetic theory;
- *Identify* a phase change based on the description of particle arrangement and temperature change.

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.8 Classify various solutions as acids or bases according to their physical properties, chemical properties (including neutralization and reaction with metals), generalized formulas, and pH (using pH meters, pH paper, and litmus paper).
Taxonomy Level: 2.3-B Understand Conceptual Knowledge

Key Concepts:
Acid: acidic solution
Base: basic solution
pH scale
Neutral solution, Neutralization reaction

Previous/Future knowledge: In 7th grade (7-5.6) students distinguish between acids and bases and use indicators (including litmus paper, pH paper, and phenolphthalein) to determine their relative pH. In chemistry (C-6) students will further develop the concepts of acids and bases by determining strong and weak acids and bases, as well as, using hydronium and hydroxide ion concentrations to determine pH and pOH of solutions.

It is essential for students to
- Understand that one of the important working definitions of an *acid* is a chemical that releases hydrogen ions (H^+) in solution and that a *base* is a chemical which releases hydroxide ions (OH^-) in solution.
- Understand that the *pH scale* is a way to measure the concentration of hydrogen ions in solution. It measures how acidic or how basic a solution is.
    - The pH of a solution can be measured using pH paper, litmus paper, or pH meters.
    - The pH range of many solutions falls between 0 and 14.
    - The pH of pure water is 7. Any solution with a pH of 7 contains equal concentrations of H^+ and OH^- and is considered a *neutral solution*. It is not an acidic or a basic solution.
    - The pH of an acidic solution is less than 7. It contains more H^+ than OH^-. A lower number indicates more hydrogen ions. The lower the number the more acidic the solution.
    - The pH of a basic solution is greater than 7. It contains less H^+ than OH^-. A higher number indicates more OH^- ions. The higher the number the more basic the solution is.
- Understand the physical and chemical properties of *acidic solutions*.
    - Acidic solutions conduct electricity (are electrolytes).
    - Acidic solutions have a tart or sour taste (Caution! Students should never taste anything in science lab).
    - Acidic solutions turn blue litmus paper red; other indicators will turn a specific color for each pH value.
    - Acidic solutions have a pH less than 7.
    - Acids react with active metals such as zinc and magnesium.
    - For the purposes of Physical Science, the formula of an acid can be recognized because the first element in the formula is hydrogen. (Since water does not give up an H^+ readily, it will not be classified as an acid in this course.)
    - Examples might include:
        - HCl Hydrochloric acid (stomach acid)
        - H_2SO_4 Sulfuric Acid (common industrial acid)

Properties and Classifications of Matter
PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

- Understand the physical and chemical properties of *basic solutions*.
  - Basic solutions have a slippery feel
  - Basic solutions conduct electricity (are electrolytes)
  - Basic solutions have a pH greater than 7
  - Red litmus paper turns blue in the presence of a basic solution; other indicators will turn a specific color for each pH value
  - For the purposes of Physical Science, the formula of a base can be recognized because the formula ends in OH.
  - Examples might include.
    - $NaOH$ Sodium Hydroxide (drain cleaner)
    - $Ca(OH)_2$ Calcium Hydroxide (hydrated lime - fertilizer)
- Understand the process of *neutralization*:
  - Acids and bases react to form water and a salt. This type of reaction is often called a *neutralization reaction* because the hydrogen ions from the acid and hydroxide ions from the base react to form water molecules (water is neutral).
  - An acid is used to neutralize a base; a base is used to neutralize an acid.
- Understand and be proficient at carrying out laboratory procedures for determining the pH of an unknown solution using pH paper or a pH meter, as well as, for determining whether an unknown substance is an acid or a base using litmus paper.

It is not essential for students to
- Understand the different theories of acids and bases (Arrhenius, Bronsted-Lowry, or Lewis);
- Understand or be familiar with the nomenclature for acids;
- Understand or be familiar with pH or pOH calculations;
- Remember the specific pH of common acids or bases;
- Differentiate between strong/weak acids and concentrated/dilute acids.

Assessment Guidelines:
The objective of this indicator is to *classify* various substances as acids or bases and various solutions as acidic or basic according to properties, formulas, and pH, therefore, the primary focus of assessment should be to categorize a substance based on the criteria in the indicator.

In addition to *classify*, assessments may require that students
- *Exemplify* acidic or basic solutions based on their properties;
- *Identify* an acid or a base using its formula;
- *Compare* acids to bases with reference to relevant characteristics which define each category;
- *Summarize* the major points which define each category; or
- *Infer* from data the correct classification (acidic or basic) of an unknown solution.